Carrier Aggregation for High Speed Data in LTE Advanced System

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***Abstract*—**One of the most important features to migrate from LTE system to LTE-A system is Carrier aggregation. It is used to achieve high data rates of the order of 1Gbps. Furthermore an LTE Advanced user is backward compatible with LTE. Carrier aggregation is a multi carrier technique, where we will be combining unused SCC with the PCC that is allocated to the user equipment. By combining five component carriers, each of 20 Mhz, we can extend the bandwidth to 100 Mhz and hence achieve high data rates. In this paper we will analyze the performance of carrier aggregation and compare it with the conventional LTE system.

***Keywords*—**Carrier Aggregation, eNodeB, Inter-Band Aggregation, Intra-Band Aggregation, LTE Advanced

***Abbreviations*—**International Telecommunication Union (ITU), Long term Evolution (LTE), Long Term Evolution-Advanced (LTE-A), Primary Component Carriers (PCC), Secondary Component Carriers (SCC)

I. INTRODUCTION

IN order to meet the high data rate demand to support various services on internet, the ITU started the standardisation process. In response to the requirements laid by ITU, the third generation partnership project introduced a feature known as carrier aggregation in their latest release. Carrier aggregation is a process where we will be sensing the unused carriers or spectrum and combine them with the PCC. Current LTE system can achieve only up to 100 mbps speeds, but by using carrier aggregation we can achieve data rates of order of 1Gbps in the downlink [Xingqin Lin et al., 2012].

For example, let us consider two different geographic cells, each served by two different base stations. Suppose in one cell some spectrum is left unused or surplus, while in other cell there may be need for additional spectrum in order to meet high data rate demands of its users. In such a case we can allocate the unused or surplus spectrum to users in other cell and combine it with the PCC of users.

1.1. Deployment Scenarios

Three deployment scenarios are possible [Al-Shibly et al., 2012], as shown in figure given below. We consider only two component carriers for example, say of frequency F1 and F2.

Scenario one: In scenario one, both the component carriers are in same band and the responses of the antennas are almost same, have same coverage [Chang Min Park et al., 2013]. Both overlap in all the areas of cell and hence carrier aggregation is possible in all the areas.

Scenario two: In scenario two, the coverage of component carrier F2 has smaller coverage than that of component carrier F1, as they are from widely separated bands. Hence carrier aggregation is possible in smaller area, where they overlap each other.

Scenario three: In scenario three, the response of one of the component carrier is purposely shifted, so as to improve the performance of users in the cell edge. Carrier aggregation is possible in cell edges also and hence users in the cell edge also experience high throughput.

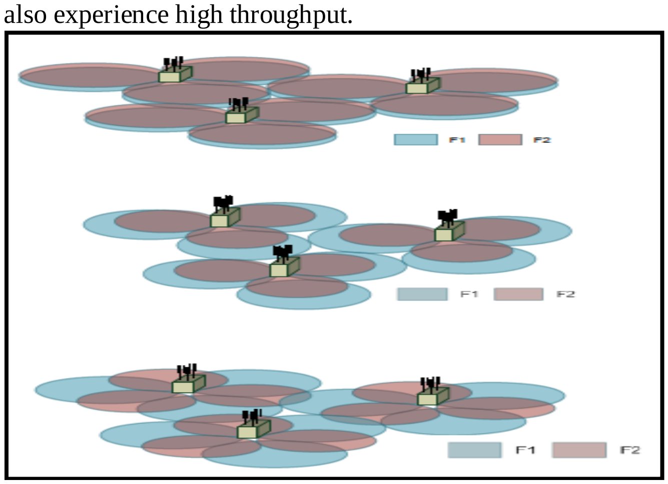

Figure 1 – Deployment Scenarios

1.2. Types of Carrier Aggregation

Based on whether the component carriers are from the same band or not and whether they are adjacent to each other in frequency domain or not, carrier aggregation is classified as intra band contiguous carrier aggregation, intra band non

contiguous carrier aggregation, inter band non-contiguous carrier aggregation [Pederesen et al., 2011]. They are also classified as symmetric and asymmetric carrier aggregation depending on the number of component carriers in the uplink and downlink [Rapeepat Ratasuk et al., 2010].

- Intra band continuous carrier aggregation: In this, both the component carriers are in same frequency band and continuous to each other in frequency domain.
- Intra band non continuous carrier aggregation: Here both the component carriers are in same band of frequency, but they are not adjacent or continuous in the frequency domain.
- Inter band non continuous carrier aggregation: In this case, the component carriers are from different bands of frequency and hence they will be always non continuous.

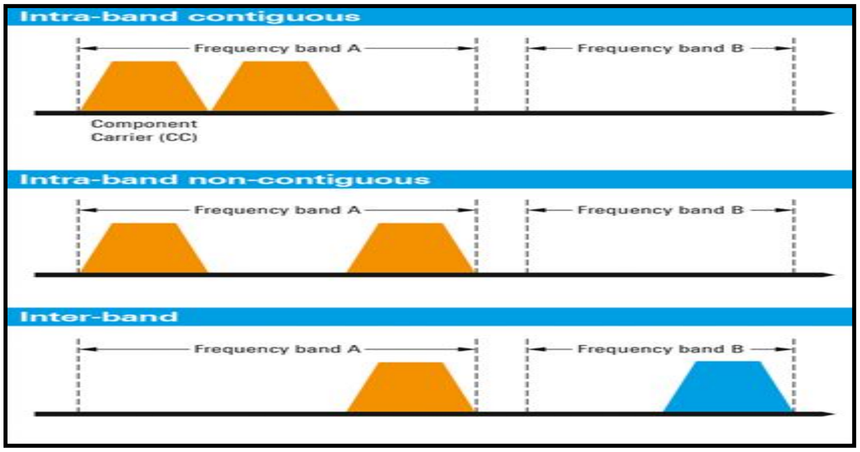

Figure 2 – Types of Carrier Aggregation

If the number of component carriers in both the uplink and downlink is same then it is said to symmetric carrier aggregation. If the number of component carriers in downlink is more than that of uplink or vice versa then it is said to be asymmetric carrier aggregation.

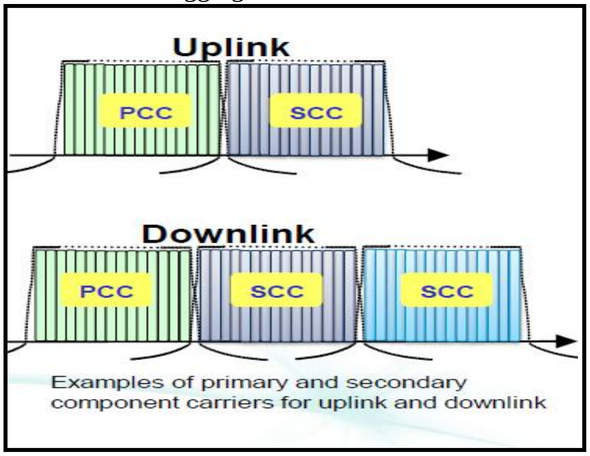

Figure 3 – Symmetric and Asymmetric Carrier Aggregation

II. LTE ARCHITECTURE

Each frame is of duration 10ms and consists of 20 slots. Each slot consists of seven symbols. Two slots constitute one sub frame. There are ten sub frames in a single frame. One Physical Resource Block (PRB) is the minimum resource element that can be assigned to a user. It consists of 12 consecutive sub-carriers, and has a bandwidth of 180 kHz [David Astély et al., 2009]. The basic architecture of the EPS contains the following network elements.

- LTE EUTRAN
- LTE Evolved Packet Core

2.1. LTE Eutran

EUTRAN consists of eNodeB. EUTRAN is responsible for complete radio management in LTE. When UE powered on eNB is responsible for Radio Resource Management, i.e. it shall do the radio bearer control, radio admission control, allocation of uplink and downlink to UE etc. When a packet from UE arrives to eNB, eNB shall compress the IP header and encrypt the data stream. It is also responsible for adding a GTP-U header to the payload and sending it to the SGW. Before the data is actually transmitted the control plane has to be established. eNB is responsible for choosing a MME using MME selection function. The QoS is taken care by eNB as the eNB is only entity on radio. Other functionalities include scheduling and transmission of paging messages, broadcast messages, and bearer level rate enforcements also done by eNB.

2.2. LTE Evolved Packet Core

The LTE EPC consists of MME, SGW, PGW, HSS and PCRF.

Mobility Management Entity (MME): The MME is a control entity. It is responsible for all the control plane operations. All the NAS signalling originates at UE and terminates in MME. MME is also responsible for tracking area list management, selection of PGW/SGW and also selection of other MME during handovers [Ibraheem Shayea et al., 2012]. MME is also responsible for SGSN (Serving GPRS Support Node) selection during LTE to 2G/3G handovers. The UE is also authenticated by MME.MME is also responsible for bearer management functions including establishment of dedicated bearers for all signalling traffic flow.

Serving Gateway (SGW): Serving gateway terminates the interface towards EUTRAN. For each UE there is a single Serving GW associated with EPS at a given point of time. SGW acts as a local mobility entity for inter eNB handovers. It also acts a mobility anchor for inter 3GPP mobility. SGW is responsible for packet routing and forwarding, buffering the downlink packets. As eNB is responsible for uplink packet marking, SGW is responsible for downlink packet marking.

PDN Gateway (PGW): PGW terminates SGi interface towards the PDN. PGW is responsible for all the IP packet based operations such as deep packet inspection, UE IP address allocation, Transport level packet marking in uplink and downlink, accounting etc. PGW contacts PCRF to determine the QoS for bearers. It is also responsible for UL and DL rate enforcement.

Home Subscriber Server (HSS): The HSS is a central database that contains user-related and subscription-related information. The functions of the HSS include functionalities such as mobility management, call and session establishment support, user authentication and access authorization. It also holds information about the PDNs to which the user can connect. In addition the HSS holds dynamic information such as the identity of the MME to which the user is currently attached or registered. The HSS may also integrate the authentication center (AUC), which generates the vectors for authentication and security keys.

Policy Control and Charging Rules Function (PCRF): The PCRF is responsible for policy control decision-making as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW. The PCRF provides the QoS authorization (QoS class identifier [QCI] and bit rates) that decides how a certain data flow will be treated in the PCEF and ensures that this is in accordance with the user's subscription profile.

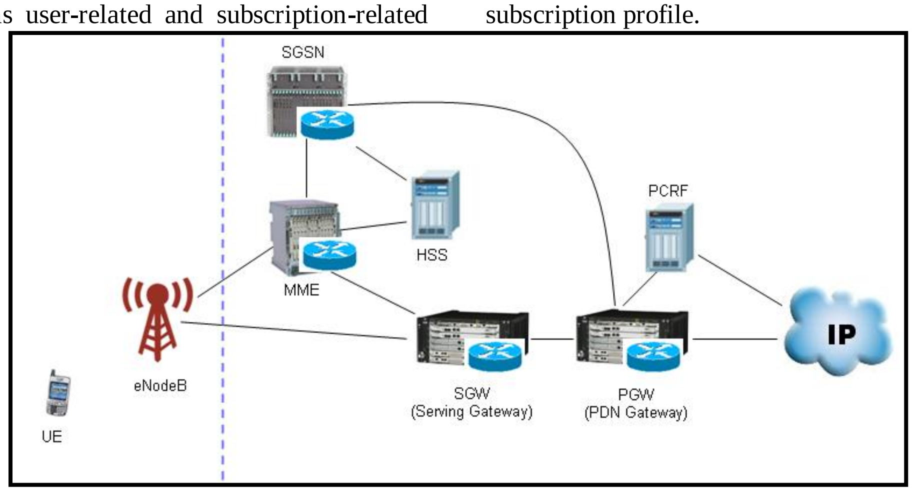

Figure 4 – LTE Architecture

III. Existing and Proposed System

Existing technologies are based on single carrier technology, i.e. only a single carrier or channel spectrum is assigned to all the users. Each channel in LTE is of 20 MHz, but still it's not sufficient for high data speeds [GK Srivastava & NK Tadkapalli, 2012]. Allocating a single carrier leads to the wastage of spectrum and hence spectrum is not utilised efficiently. Also the user equipment gets very less speeds, only upto 100mbps for the downlink in the LTE system.

Therefore in order to overcome the drawbacks of the existing systems and to achieve high data rates of the order of 1Gbps, we propose a multi carrier technique called carrier aggregation. Instead of assigning a single carrier to user equipment, five component carriers each of 20 Mhz are aggregated and assigned to a user. It will lead to high data rates of the order of 1Gbps and also the spectrum is utilised efficiently.

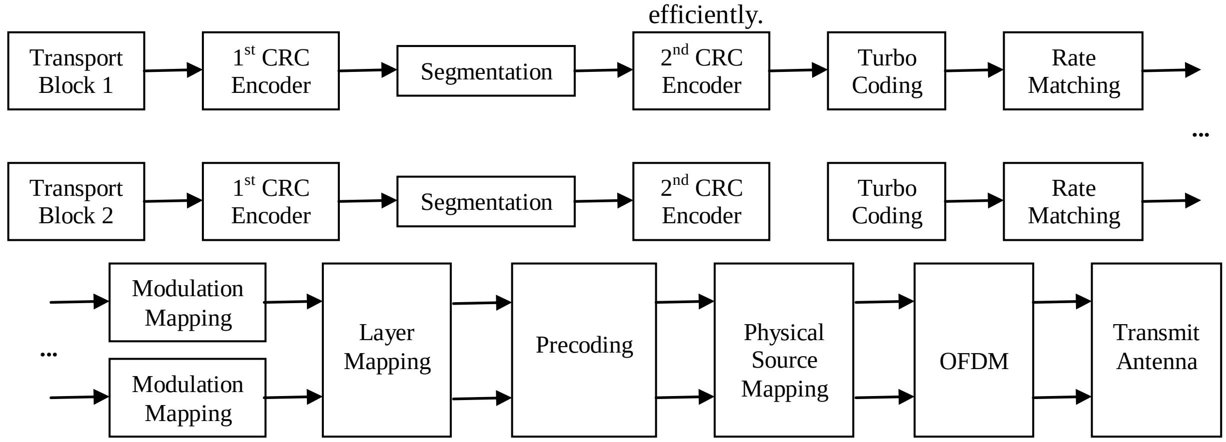

Figure 5 – Channel Processing in LTE

IV. Simulation Results

The simulation has been done entirely using matlab. After modelling the entire channel processing between the user equipment and the LTE base station, we generated an LTE carrier. The channel processing includes CRC attachment, Segmentation, turbo coding, Rate matching, modulation mapping, layer mapping, precoding, physical resource mapping, OFDM modulation, as shown in figure 5. The modelling has been done according to the 3gpp specifications laid for LTE. Figure 6 shows the spectrum of individual component carriers obtained after channel processing. As shown in figure 7, five carriers, each of 20 MHz obtained from LTE channel processing have been aggregated to get a overall bandwidth of 100Mhz. With such a large bandwidth we can get data rates of order of 1Gbps. Figure 8 shows the Non continuous carrier aggregation.

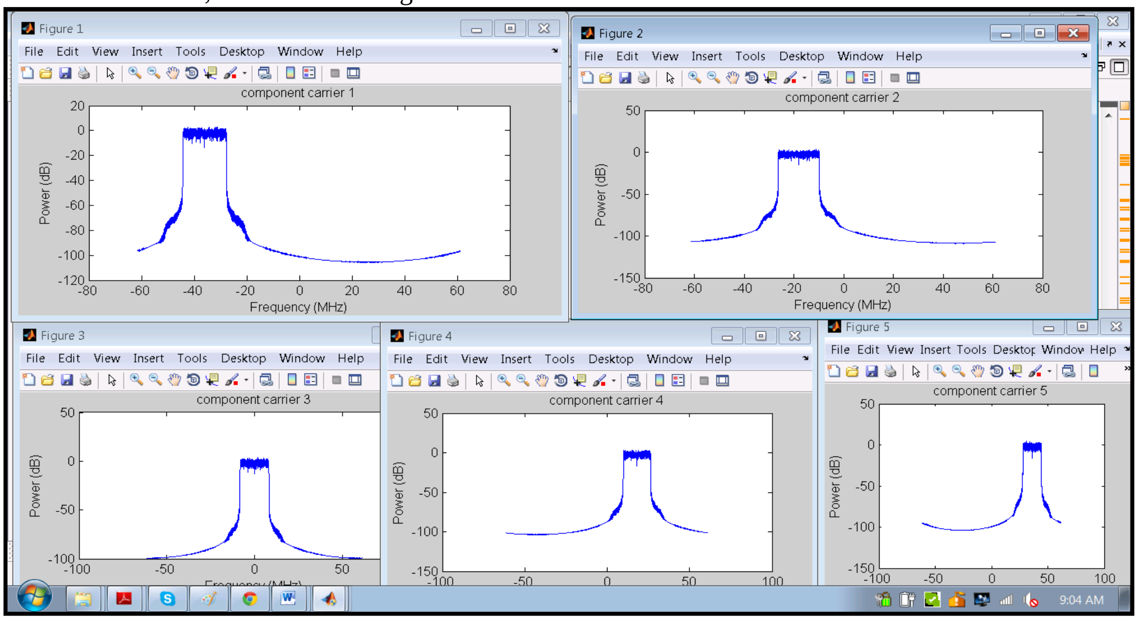

Figure 6 – Individual Component Carriers

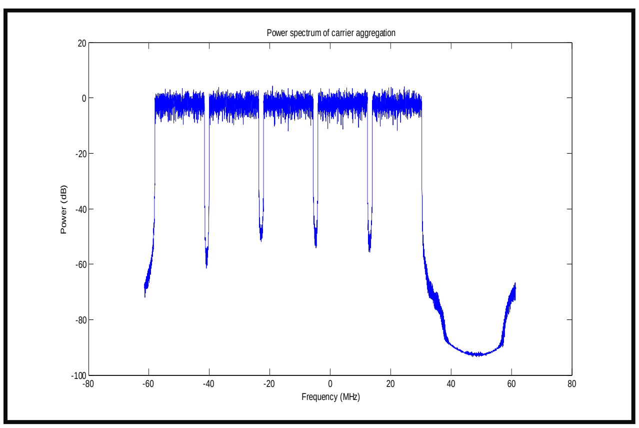

Figure 7 – Continuous Carrier Aggregation

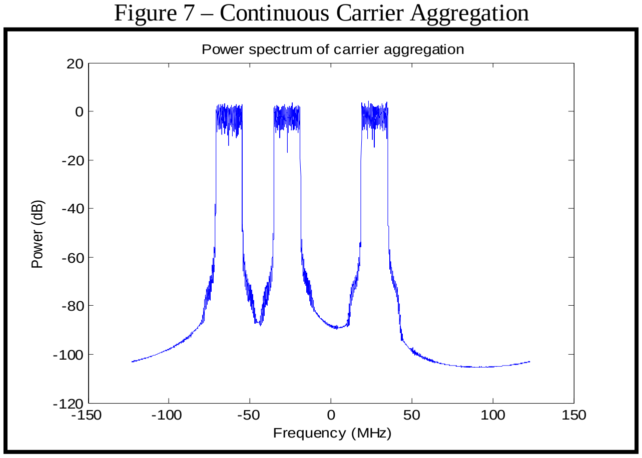

Figure 8 – Non Continuous Carrier Aggregation

V. Conclusion

Carrier aggregation proves to be an efficient and economically feasible technique, which could greatly enhance the data rates that can be achieved. Carrier aggregation for five component carriers has been simulated and it has been found that carrier aggregation can provide data rates of 1 Gbps. The conventional LTE can provide data rates only up to 100 mbps. By using carrier aggregation, data rate is increased by ten times. Carrier aggregation will continue to be one of the most important techniques in next coming generations of communication industry. In future it can be even extended to heterogeneous system.

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